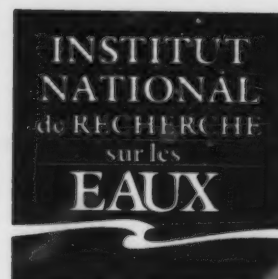
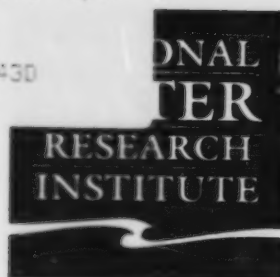


Environment Canada Environnement

National Water Research Institute (Canada). R
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Date: 1990/91

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RESEARCH AND APPLICATIONS BRANCH

ANNUAL REPORT

1990-91



RESEARCH AND APPLICATIONS BRANCH

ANNUAL REPORT

1990-91

**National Water Research Institute
Burlington, Ontario L7R 4A6**

July 1991



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 APPENDIX - BRANCH PERSONNEL	

List of Acronyms

AAS	Atomic Absorption Spectroscopy
AED	Atomic Emission Detector
C&P	Conservation and Protection
CAPCO	Canadian Association of Pesticide Control Officials
CCIW	Canada Centre for Inland Waters
CEPA	Canadian Environmental Protection Act
CI	Chemical Ionization
CRM	Certified Reference Material
CZE	Capillary Zone Electrophoresis
DBD	Dibenzo- <i>p</i> -dioxin
DBF	Dibenzofuran
DNA	Deoxyribonucleic Acid
ECD	Electron Capture Detector
EI	Electron Impact
EMFS	Eulerian Model Evaluation Field Study
FTB	Floating Tire Breakwater
GC	Gas Chromatography
HPLC	High Performance Liquid Chromatography
IA	Immunoassay
IJC	International Joint Commission
IWD	Inland Waters Directorate
LC	Liquid Chromatography
LEAF	Laser Excited Atomic Fluorescence
LRTAP	Long Range Transport of Airborne Pollutants
MAB	Monoclonal Antibodies
MEKC	Micellar Electrokinetic Chromatography
MISA	Municipal-Industrial Strategy for Abatement
MS	Mass Spectrometry
MSD	Mass Spectrometry Detector

List of acronyms (continued)

NICI	Negative Ion Chemical Ionization
NWQL	National Water Quality Laboratory
NWRI	National Water Research Institute
OC	Organochlorine Compound
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCDD	Polychlorinated Dibenzo- <i>p</i> -dioxin
PCDF	Polychlorinated Dibenzofuran
PERD	Panel on Energy Research and Development
PESTMYOP	Pesticide Multi-Year Operational Plan
PFB	Pentafluorobenzyl
PPWB	Prairie Provinces Water Board
PWC	Public Works Canada
QA	Quality Assurance
QC	Quality Control
RAB	Research and Applications Branch
RFA	Resin and Fatty Acids
RIA	Radioimmunoassay
RM	Reference Material
RRB	Rivers Research Branch
SFE	Supercritical Fluid Extraction
SWADE	Surface Wave Dynamics Experiment
TCDD	Tetrachlorodibenzo- <i>p</i> -dioxin
USGS	U.S. Geological Survey
WPMB	Water Planning and Management Branch
WQB	Water Quality Branch
WRB	Water Resources Branch
WSC	Water Survey of Canada

Preamble

In keeping with our established practice, it is my pleasure to present to our clients, collaborators and colleagues this annual report covering the activities of the Research and Applications Branch, National Water Research Institute, for the period April 1, 1990 to March 31, 1991.

Requests for additional information or comments related to material presented in this report should be directed to the appropriate study leader or the Branch Director's Office.

John Lawrence
Director



Overview

J. Lawrence, Director

The Research and Applications Branch (RAB) is one of the three research branches of the National Water Research Institute (NWRI). The activities carried out under our research program are grouped into three separate projects: Analytical Chemistry Research, Quality Assurance and Hydraulics Studies. This annual report is intended to provide a summary of these activities through brief descriptions of the general orientations of each project and progress reports for each study either pursued or completed during 1990-91.

In the area of analytical chemistry, our efforts are directed toward the development of sensitive and cost effective methods for the determination of chemical and biochemical parameters in various types of environmental samples. Our assistance and expertise is sought for the development of reference analytical methods required in the context of departmental regulatory or control initiatives being considered as part of the implementation of the Canadian Environmental Protection Act (CEPA). The Branch also plays a lead role in quality assurance/control matters associated with the scientific data measurement component of many programs within Conservation and Protection. The Hydraulics research generates new knowledge of the dynamics of water to provide a framework for the management of water resources and aquatic ecosystems. The interfaces between water and the atmosphere, bottom sediments and shores are studied to gain a better understanding of mechanisms controlling the transport of pollutants and erosion.

Our research efforts focus on enhancing the science base of Environment Canada's priority areas and many of our studies provide direct support to a broad range of programs, namely CEPA assessment and regulatory programs, the Long Range Transport of Airborne

Pollutants program, and various water quality programs. Major clients for the output of RAB activities include other NWRI branches, national and regional laboratories operated by the Water Quality Branch or Environmental Protection, the Water Resources Branch, provincial environmental agencies and the private sector.

The Branch continues to seek opportunities for the transfer of NWRI technology to users in the university and private industry sectors. As well, the use of a wide range of specialized equipment, services and facilities that can be found in the Institute is actively promoted to external parties within the usual cost recovery guidelines set by Treasury Board.

Analytical Chemistry Research Project

I. Sekerka, Project Chief

Introduction

The research activities grouped under the Analytical Chemistry Project have been developed to address primarily the priority needs in this area that are identified by various sectors of Environment Canada as well as to contribute to the development of new scientific knowledge. As a department operating several laboratories and a wide range of programs that are crucially dependent on obtaining reliable chemical analytical data, Environment Canada has a continuing need for research work that will ensure the timely development and maintenance of expertise in selected areas covering various aspects linked to the development and improvement of analytical methods.

Through some nine studies carried out as part of the Project, the emphasis is placed on specific aspects of analytical methods used for the detection of parameters of interest in environmental samples. While some studies are more concerned with the development or the improvement of the sample preparation steps of analytical protocols, others are focused on determining the most efficient means to detect, separate and quantify specific constituents of environmental samples. Also as part of the Project, expert advice and assistance is provided for the operation of a mass spectrometer laboratory and of installations dedicated to work involving hazardous substances or requiring ultra-clean conditions. The output of these research activities continues to be of relevance to the laboratory work carried out across the Department and provides direct support to the environmental measurement component of programs such as those linked to the implementation of the Canadian Environmental Protection Act and various water quality agreements involving Environment Canada.

Highlights

The research to investigate the full potential of incorporating supercritical fluid extraction into analytical protocols has been continued with a study on the application of the technique for the extraction and separation of polychlorinated dibenzo-*p*-dioxins (PCDD) from incinerator fly ash samples. The results obtained highlight advantages of the method in terms of efficiency, reproducibility and recoveries when compared with conventional extraction techniques employing organic solvents.

As part of efforts to design a radioimmunoassay technique capable of screening environmental samples for their PCDD content prior to subjecting them to more sophisticated and costly analysis techniques, an assay incorporating the use of tritiated tetrachlorodibenzo-*p*-dioxin as a tracer radioligand has been developed. Tests on this assay have produced promising results in terms of performance and sensitivity.

Success was achieved in finding steps to overcome typical interference problems encountered in the determination of low levels of lead in water samples using conventional atomic absorption spectroscopy (AAS) techniques. It was found that the addition of a mixture of ammonium tartrate-nickel tartrate as part of the sample preparation step, coupled with the use of tungsten furnace AAS system resulted in superior performance for this type of determination, with excellent detection limits and sensitivity readily achieved. The ammonium-nickel salt mixture serves to adjust the pH and acts as a matrix modifier when added to the sample to be analyzed.

After completing a positive feasibility study on the development of a laser excited atomic fluorescence (LEAF) spectrophotometer for use in the analysis of metals at the ultra-trace level in environmental samples, the work has been shifted to assembling the components of the first prototype instrument in Canada. So far excellent results have been obtained demonstrating the instrument's capability to detect sub-ppt levels of lead. Further research will be focussed on

optimizing the laser source and improving the general performance of the system. As well the application of the methodology for the determination of other trace elements will be investigated.

Laboratories, such as the National Water Quality Laboratory, involved in traditional routine analyses on environmental samples are confronted with the requirement to carryout large numbers of Kjeldahl nitrogen determination procedures on these samples. Assistance has been provided to NWQL with various aspects covering the design, construction and installation of a robotic system that will be used to automate many steps of the analysis procedure.

In support of CEPA regulatory or control initiatives currently under development and focussed on the effluents of Canadian pulp and paper mill installations, specific research studies have been carried out to address the determination of particular group of substances in environmental samples. A method has been developed for the determination of levels of non-chlorinated dibenzo-*p*-dioxin and dibenzofuran in compounds used as defoamers. A subsequent interlaboratory comparison study of this method provided the necessary evidence of adequate reliability and sensitivity for its eventual adoption as a reference method. In another study, a method for the determination of resin acids in pulp and paper sediments sampled in effluent receiving waters was developed and demonstrated to have suitable characteristics for use as part of environmental monitoring activities in that industrial sector.



Quality Assurance Project

A.S.Y. Chau, Project Chief

Introduction

Several studies have been developed under the Quality Assurance (QA) Project to provide expert assistance and advice in support of data gathering activities that involve Environment Canada, either directly or through collaboration with other agencies. These studies are primarily concerned with quality assurance aspects linked to the measurements of organic and inorganic parameters in environmental samples. While much of the emphasis continues to focus on QA support to various federal-provincial water quality monitoring programs, an increasing level of activity is being directed to QA issues associated with the development of regulatory or control measures under the Canadian Environmental Protection Act (CEPA). Also, external requests are received in increasing numbers for access to the QA expertise developed over the years, attesting to the acknowledged Canadian leadership role established in this area. Viewed over the long term, all the activities carried out under the QA Project can only contribute positively to promoting the crucial importance of quality assurance to ensure the gathering of reliable and valid environmental data.

Typical project activities include the design, implementation and assessment of inter-laboratory comparison studies for analytical determination of specific parameters. Significant efforts are also directed to the development, preparation and storage of reference materials for use in analytical chemistry work focused on contaminants of interest found in water and sediment samples.

Highlights

Interlaboratory studies have been continued as in previous years in support of the Long Range Transport of Airborne Pollutants (LRTAP), Prairie Provinces Water Board (PPWB) and Federal-Provincial Water Quality Agreement (FPQA) external quality assurance programs. The number of laboratories participating in these studies has remained comparable to that of past years. In view of the growing volume of data accumulating under these studies, efforts have been devoted to the development of a streamlined system that will provide for efficient storage and retrieval of the data needed in the course of statistical evaluation work.

Quality assurance activities in support of CEPA programs involved the design and implementation of an interlaboratory comparison study designed to validate an analysis method required as part of the monitoring of non-chlorinated dibenzo-*p*-dioxin and dibenzofuran in substances used as defoamers in the pulp and paper industry. Another interlaboratory study was undertaken to address the detection of butyltin compounds in environmental samples.

The last interlaboratory study in support of the Eulerian Model Evaluation Field Study (EMFS) was completed during the review period. An overview report summarizing and analyzing the results of the complete set of 27 studies carried out over the last two years is in preparation and will be submitted to the managers of the EMFS project.

Work has been started toward the development of a reference material for atmospheric organic contaminants in rainwater. Initially, the bulk of the activity in this area has been concentrated on organizing the logistics for the sampling of large samples of rainwater.

Upon request from external clients, such as the British Columbia Ministry of the Environment, the Ontario Ministry of the Environment and the Canadian Association of Environmental Analytical Laboratories, cost recovery arrangements were negotiated for the provision of quality assurance assistance and services in support of specific on-going activities within these organizations.

Hydraulics Studies Project

M.G. Skafel, Project Chief

Introduction

The Hydraulics Studies Project conducts mission-oriented applied and basic research on fluid mechanics subjects relevant to the environment; operates the hydraulics and sedimentology laboratories of NWRI and provides technical support to professionals using these laboratories. The Project also includes the National Calibration Service, with the Water Survey of Canada (WSC) continuing to be the principal client, for the maintenance and calibration of flow meters. We also actively pursue a programme of technology transfer by marketing the facilities and services of the laboratories to clients outside NWRI.

The research component of the Project is concentrated in three areas: fluvial engineering, coastal engineering, and physics of the air-water interface. The fluvial engineering studies address river process issues such as the measurement of discharge and sediment transport, and flow-structure interaction. The Water Resources Branch is by far the single largest client for our expertise in this area. The studies in coastal engineering focus on environmental issues such as shoreline evolution, water levels, sediment transport, and development of design criteria to reduce environmental risk. The coastal issues we address are of direct relevance to the Water Planning and Management Branch's involvement in the IJC Water Levels Reference, and to Environmental Protection's mandate to vet new development on the shores and coasts, as well as to other coastal managers. Studies on the physics of the air-water interface seek to parameterize accurately the fluxes of mass, momentum, energy and heat across the air-water interface and to develop modelling capability for such diverse issues as the transport of toxics, climate change, mixing in the upper layers, and wave forecasting. In the past, research on the physics of the air-water

interface and on waves found support in engineering applications, but a new role has emerged: it is an essential component of the expanding world climate research and global change programmes.

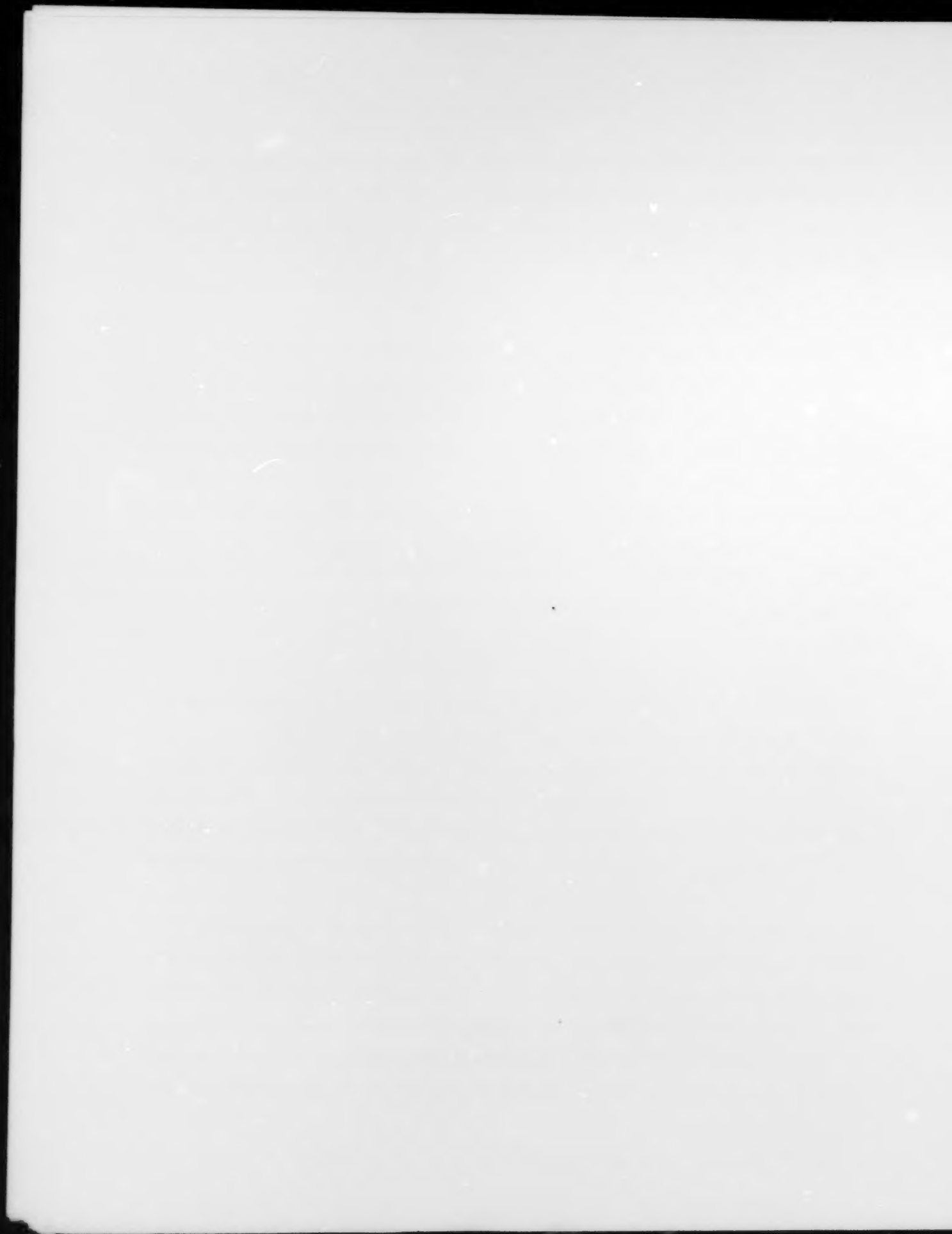
Highlights

Measurement of suspended sediment in rivers is a vital component in assessing the pathways of pollutants. Several activities this year have been directed towards improving the departmental capability in this area. We are working with WSC to develop a strategy for calibration of sediment samplers, and have completed quality control tests on standard sampler nozzles. The operating characteristics of the US DH-81 suspended sediment sampler were evaluated. The range of flows, under which iso-kinetic conditions (flow into the sampler is the same velocity as the ambient so the sediment load into the sampler is representative of the ambient sediment load) are satisfied, were determined. This work has resulted in plans to develop a self-regulating iso-kinetic sampler next fiscal year.

A new initiative is well underway to explore the evolution of a till shoreline under the influence of waves and varying water levels. Much of the shoreline of the lower Great Lakes is composed of glacial till, composed primarily of pre-consolidated clay and silt. When it is exposed to the forces of waves and changing water levels it does not respond like sand shores, which have been studied extensively in the past. Physical model tests are continuing in the large wave flume and will provide new knowledge for the numerical models. The latter will be used to predict the evolution of till shorelines.

The largest single activity in the project this year has been the scientific leadership of and activity in the Surface Wave Dynamics Experiment (SWADE), sponsored primarily by the US Office of Naval Research and the US National Aeronautics and Space Administration. This international experiment is designed to improve our understanding of wave evolution, the coupling between the atmosphere and the oceans and lakes (vital for weather prediction and climate modelling), and on the response of remote sensing devices to the surface. The field

experiments were successfully completed by the end of the year. After the catastrophic loss of the main sensor platform, a replacement sensor suite was assembled and installed on a Fisheries and Oceans Canada vessel. Not only was this substitution successful, it provided significant advantages over the lost spar buoy.



ANALYTICAL CHEMISTRY RESEARCH



Mass Spectroscopy Laboratory

(84006)

H.B. Lee, Study Leader
J.M. Carron and R.J. Wilkinson, Collaborators

Introduction

Mass spectrometers are widely used in the analysis and confirmation of trace organics in environmental samples. Although a number of smaller quadrupole mass spectrometers are in use at CCIW for simple and routine applications, these units have low resolution, lack the flexibility of providing different ionization techniques and have limited means of sample introduction and interface. In order to support analytical services and research activities of more demanding mass spectral requirements, a mass spectroscopy laboratory was jointly set up sometime ago by NWRI and NWQL. A VG Tribrid mass spectrometer was acquired because of its flexibility to be operated in both EI and CI (positive and negative ions) modes, the presence of both magnetic sector and quadrupole analyzers for MS-MS work, the availability of various interfaces for LC-MS work and the availability of a dioxin quantitation package.

Results

After experiencing considerable software and hardware problems at various stages of the installation of the Tribrid, a major milestone was reached last fiscal year when the front end of the instrument became fully operational. As part of the evaluation of the capability of the system, investigative work was undertaken for the quantitation and confirmation of dioxins in sample extracts. With a clean ion source and operating at a resolution of 2000, a sensitivity of

400 fg (10^{-15} g) for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin was achieved by monitoring three to four ions. This sensitivity is at least a few times better than the best that could be obtained by the Finnigan INCOS 50 system or a Hewlett-Packard Mass Selective Detector. Since the Tribid has a maximum rated resolution of 7500, this instrument will not be suitable for dioxin analysis in those protocols which require a resolution of 10000 or higher.

Other successful investigative work performed during the year included the quantitation and confirmation of neutral herbicides under EI mode as well as PCBs, OCs and pentafluorobenzyl esters of acidic herbicides in negative ion chemical ionization mode. The results indicated that the Tribid is an adequate instrument for method development research or routine analysis involving these compounds. The evaluation of the Tribid's LC-MS capabilities could not be pursued because of the lack of a suitable HPLC pump.

Through self-training and some brief and informal training by VG personnel, two operators are now fully capable of running the MS for dioxin and the other analyses mentioned above and performing minor routine maintenance on the instrument.

Electrokinetic and Enzymatic Detection of Subcellular Toxic and Mutagenic Effects

(84007)

S.A Daniels, Study Leader

Introduction

The genotoxicity of a substance, that is the ability to cause adverse interactions with nucleic acids at the cellular level, constitutes an important consideration under most hazard assessment schemes for environmental contaminants. This situation continues to stimulate research in analytical chemistry for the discovery of techniques capable of detecting evidences of genotoxic effects. Any success in this research would find application in laboratories where there is a crucial need for effective screening tools so as to ensure that sophisticated and costly analytical techniques are limited to samples warranting such procedures.

The present study is intended to investigate approaches considered to be promising for the separation and analysis of the adducts resulting from the interactions between nucleic acids and a genotoxin. Two high resolution separation techniques, namely gel electrophoresis and capillary zone electrophoresis (CZE), will be used for the preparation and collection of nucleic acid fragments resulting from the enzymatic hydrolysis of standard DNA material that has been exposed to genotoxic substances. Also, under a collaborative arrangement with scientists at the National Research Council of Canada laboratory, in Halifax, NS, an ion-spray mass spectrometry technique will be studied for the detection, identification and quantification of the adducts. As well, optimal conditions for the coupling of this mass spectrometry technique with capillary zone electrophoresis and liquid chromatography will be explored.

Results

Benzo(a)pyrene is recognized as a strong mutagen and was chosen as the model compound in our study of the interactions between a genotoxin and DNA. Preliminary results have shown that quantitative separation of nucleic acid fragments or adducts resulting from such interactions can be achieved with gel electrophoresis, although the difficulty of producing hard copies of the DNA gels needs to be addressed and solved. However, a reassessment of the study plan has resulted in the postponement for the time being of further work in this particular area.

A procedure for identifying and quantifying nucleic acids by capillary zone electrophoresis was developed. Efforts are continuing to find how to eliminate the inconsistent performance experienced so far with this separation system.

The mass spectrometry investigation of nucleic acid adducts has required the synthesis of appropriate compounds. More than 50 nucleic acid components were examined by various mass spectrometry systems (MS, MS/MS, LC/MS). All compounds showed excellent sensitivity under ion-spray mass spectrometry (ISP/MS). Conditions for creating a reliable interface between CZE and ISP/MS components have been successfully determined and reproducible data were obtained. The promising results obtained so far in this portion of the study warrant its continuation.

**Development of a Multi-Detection System for
Liquid Chromatography Techniques
(84008)**

B.K. Afghan, Study Leader

R.J. Wilkinson, Collaborator

Introduction

When it comes to the chemical analysis of organic compounds in environmental samples, gas chromatography (GC) and high performance liquid chromatography (HPLC) are the most widely used procedures. It is generally accepted that GC methods are somewhat superior to HPLC methods when considering the range of detectors available for the determination of analytes of interest at appropriate levels of sensitivity and specificity. The distinct advantage of HPLC lies in its separating power which is potentially greater than that of GC because of the possibility to vary over a much wider range the factors affecting the separation.

This study has been designed to explore conditions under which various detection techniques can be successfully interfaced with a HPLC system. Detection techniques to be investigated include spectroscopy-, electrochemistry- and mass spectrometry-based systems. The development of a multi-detection capability for coupling to a HPLC system would be highly valuable in the quantitative analysis and confirmation of priority toxic chemicals in various environmental matrices.

Results

A HPLC-multi-detection system has been configured, incorporating the following components: a Waters 840 data and chromatography control assembly, an ultra-violet (254 nm) detector and a fluorescence detector. A series of experiments were carried out on the system and appropriate corrective steps implemented in order to reproduce results obtained previously under similar conditions and achieve the performance capability specified for the system.

Work is continuing to interface the system with other detection techniques, such as photodiode array, chemiluminescence, voltametry and conductometry detectors. The optimization of the operating condition of the full multi-detection system will be carried out through test runs for the analysis of compounds such as polynuclear aromatic hydrocarbons, carbamates and phenols.

Separation and Extraction Techniques

(84011)

F.I. Onuska, Study Leader

K.A. Terry, Collaborator

Introduction

This study continues to be focussed on investigations of recently developed separation or extraction techniques to determine their full potential usefulness in determinations of organic contaminants in various environmental samples. During last fiscal year, efforts have been directed at two such techniques, capillary zone electrophoresis (CZE) and micellar electrokinetic chromatography (MEKC). Also, as part of on-going research on supercritical fluid extraction (SFE) techniques, the extraction of polychlorinated dibenzo-*p*-dioxins (PCDDs) from municipal incinerator fly ash samples was studied and the results compared with those obtained when more traditional techniques involving organic solvents are used.

Highly efficient separations of ionic and non-ionic micellar solutions have been achieved with CZE and MEKC techniques which involve the application of high potential electrical fields to these solutions. Besides giving good separation, the approach can be used with ultra-small volume of samples, thus holding much promise for its use with environmental samples. This type of chromatography, however, still suffers some limitations in that, on account of physical similarities often encountered between the solutes and the separation media, a detector of universal application has yet to be developed. Establishing the potential usefulness of a longitudinal UV absorption cell in comparison to the on-column detection system utilized usually has been set as the main objective of the study.

Results

A custom made CZE system has been assembled with modular components so as to enable systematic studies of capillary electrophoresis and other related techniques. The system has been fully tested and good performance results have been obtained. Different sample introduction techniques were tested with polar model compounds such as phenols, chlorinated phenols, organic acids and amines. The electrokinetic sampling mode was shown to be the most suitable and reproducible one for introducing a sample onto the column. A variable pathlength longitudinal flow cell for UV detection was designed as part of the study and this innovative approach has given excellent results, particularly in terms of improved sensitivity. Moreover, the approach has the advantage of being readily applicable with high performance liquid chromatography and supercritical fluid chromatography methods. The evidence accumulated so far in the areas of reproducibility of migration time, colour efficiency, resolution, quantification, and range of application points to MEKC techniques as being well suited for the analysis of environmental samples. For instance, this novel approach could be used for the direct determination of phenols at the ppb level in a sample without the derivatization step normally required.

In the study of the supercritical fluid extraction of PCDDs from municipal incinerator fly ash, various sets of experimental conditions have been investigated to determine the optimal ones. When compared with conventional Soxhlet extraction techniques, the SFE techniques proved to offer distinct advantages in terms of extraction efficiency, time saving and minimizing exposure of laboratory personnel to organic solvents.

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Preconcentration for Ultra-Trace Analysis

(84012)

D.H.J. Anthony, Study Leader

Introduction

The ability to perform unambiguous ultra-trace determinations of organic contaminants in freshwater samples constitutes an important aspect of water quality management programs. A significant contribution in this area was made with the new technology developed by NWRI scientists a few years ago for the continuous flow extraction of large volume aqueous samples with organic solvents. Activities are continuing under this study to develop improvements for this technology and determine the full range of its applications.

Until now, the large sample extraction technology has been developed around the use of dichloromethane as the extraction solvent. In view of growing environmental and health hazard concerns with this substance, efforts are directed at developing a technique that would allow the recovery of the solvent dissolved in the extracted water before discharge in the environment. Also, exploring alternative approaches to the use of organic solvent was set as a study goal, focusing on means to incorporate supercritical fluid extraction (SFE) principles in methods for the determination of organic contaminants in water samples.

Results

Laboratory and field-testing of a prototype large sample extractor incorporating solvent recovery has been completed. The field work portion of the study was carried out at the Water

Quality Branch monitoring station located at Niagara-on-the-Lake, Ontario. While encouraging results were obtained with the operation of the instrument under laboratory and field conditions, a more definitive assessment awaits the analytical results of these experiments.

A commercial SFE system has been purchased and installed and the experimental phase with the sample collection techniques and detection methods has been initiated.

Trial runs have been carried out for the development of a large sample extraction method that could be applied for the preconcentration of organic contaminants from bog waters. Samples obtained as part of this work have been submitted for analysis.

Direct assistance was provided to staff of the Quality Assurance Project for the incorporation of the large sample extraction technology in their attempts to collect a large sample of rainwater (*cf* Study 84024). Also, in response to separate requests made by Environment Canada staff in Vancouver, B.C. and Fisheries and Oceans Canada staff in Burlington, Ontario, assistance and advice was provided on the use of the large sample extraction technology.

Development of Automated Analytical Systems (84013)

I. Sekerka, Study Leader

J.F. Lechner, J. Ford and N. Madsen, Collaborators

Introduction

Faced with an increasing workload, both in terms of number of samples processed and the numerous types of procedures involved, environmental analytical laboratories are reviewing the various areas in their operations to establish where and how automation could contribute improved efficiency. This situation applies to a large laboratory such as the National Water Quality Laboratory (NWQL) and this study has been developed to provide NWQL staff with research support in the area of laboratory automation. Important benefits usually gained from automation include efficiency in operations, reproducibility of results and a significant reduction in the frequency of foul-ups attributable to human error. The areas of activity covered under this study during the last fiscal year were planned in close consultation with NWQL staff.

Results

Assistance was provided for the design, assembly and installation of a robotic system for the determination of Kjeldahl nitrogen within the NWQL facilities. A large number of samples submitted to NWQL require this type of analysis and the incorporation of automated steps in the procedure will greatly enhance efficiency and reliability in this area. The system was fully operational at the end of the reporting period and is scheduled to undergo extensive testing over the coming months under normal routine operating conditions.

As part of continuing work to bring improvements in continuous flow analysis systems, an automated procedure has been developed to accommodate in-line pretreatment of liquid samples. This procedure is essentially based on alternating the streams of carrier solution and sample solution in the following portions of the integrated system: sample pretreatment, chemical reaction, detection and quantification. This technique was successfully applied in a new method developed for the determination of cyanide and ammonia in water samples.

New operating conditions have been determined for improving the sensitivity and selectivity of the multi-element heavy metal determinations by cathodic differential pulse stripping voltametry. One noteworthy aspect of these modifications is the elimination of the requirement for the use of a mercury drop electrode through its substitution by a rotating glassy carbon electrode.

A new simple and economical method has been developed for the determination of low levels of lead in various water samples. The method is based on the application of atomic absorption spectroscopy under operating conditions including the use of a Zeeman modulated tungsten ribbon furnace and the addition of a novel modifier to the sample as part of the sample preparation steps. Results have shown that the addition of ammonium tartrate - nickel nitrate to the water sample to act as a matrix modifier and adjust the pH causes the elimination of analytical interferences attributable to non-volatilized substances present in the sample. When compared with other types used conventionally, the new modifier has been shown to result consistently in a superior performance of the analytical method. A detection limit of 1 ppb with a relative standard deviation of less than 10% was achieved. This detection limit could even be lowered to 0.1 ppb for large volume samples by the use of a multiple sample injection procedure.

Publications

Sekerka, I. and J. Lechner. 1991. Determination of Lead in Water by Flameless Atomic Absorption Spectrometry and Nickel-Ammonium Tartrate Modifier. NWRI Contribution 91-106 (accepted for publication in *Anal. Chim. Acta*).

Sekerka, I. and J. Lechner. 1991. Determination of Cyanide by Continuous Flow Iso-Thermal Distillation with Amperometric Detection. NWRI Contribution 91-108.

Sekerka, I. and J. Lechner. 1991. Alternating Carrier-Sample Gas Diffusion Method with Conductometric Detection for the Determination of Ammonia. NWRI Contribution 91-110.

Presentations

Sekerka, I. Valving Systems for In-Line Sample Treatment Suitable for Continuous Flow Analysis. Poster presentation at the Euroanalysis VII Conference, Vienna, Austria, August 1990.

Broad Spectrum Analysis

(84014)

B.F. Scott, Study Leader

R. Sampson and J.G. Zakrevsky, Collaborators

Introduction

Traditionally, gas chromatography (GC) analysis results are reported solely in terms of those peaks in the chromatogram that are related to the target compounds present in the sample analyzed. These peaks represent a small portion of the information that modern computer-assisted GC systems are capable of producing and storing in discrete result files. The present study is intended to explore how to maximize the information that could be derived from such result files generated in the course of the routine GC analysis of environmental samples. The results of this study are expected to provide valuable knowledge in support of departmental monitoring activities. Since advances in this field of study are likely to find direct application in the operations of Environment Canada Water Quality Branch laboratories, WQB staff provided strong support for the initiation of research in this area.

As part of the study, the research work is directed in several areas where progress must be achieved in order for the overall initiative to be successful. For instance, result files collected on different instruments need to be successfully reformatted to a common format to allow their easy transfer and use in various computer-assisted data manipulation techniques. Also, recent instrumentation developments must be investigated for their possible incorporation in a broad spectrum analysis scheme. Success in this research should culminate with the development of

an expert system whereby artificial intelligence programs are designed to address for example the specific requirements of particular GC analysis operations.

Results

Much of the analytical data generated in the National Water Quality Laboratory from various types of instruments is transmitted to a central HP 1000 computer system for storage and processing. An atomic emission detector - gas chromatography (AED-GC) system has been recently installed in the laboratory and was connected to the HP 1000 network as an additional workstation. Result files generated by the computer component of the AED-GC instrument have been successfully transmitted to the HP 1000 computer after appropriate reformatting. With this achievement, a significant milestone and a major step in this study have been reached as it is now possible to plot on the same computer screen or report page the chromatograms of the same sample obtained from different GC systems and stored in separate result files, namely one coupled to an atomic emission detector and the other to an electron capture detector. Further work in this area is now required to find ways to manipulate the data so that the superimposition of such chromatograms can be realized.

During the evaluation of the role AED-GC technique could play in broad spectrum analysis, additional valuable information was gained with the discovery of its advantageous application in the analysis of organotin compounds in various types of environmental samples. It has been possible to establish conditions under which this analytical method can provide results that can be favourably compared to those obtained with methods conventionally used up to now, in terms of sensitivity, number of species detected and cost.

Publications

Scott, B.F., Y.K. Chau and A. Rais-Firouz. 1990. Determination of Butyltin Species by GC/Atomic Emission Spectroscopy. NWRI Contribution 90-126.

Scott, B.F. and A. Cassista. 1990. Analysis of PCB Congeners in Fuels. NWRI Contribution 90-129.

Presentations

Scott, B.F. Analysis of Fuels for Organo Sulphur and Phosphorus Compounds Using an Atomic Emission Detector. Presented at the 4th International Environmental Contamination Conference, Barcelona, Spain, October 1990.

Operation of the Clean and Hazardous Chemicals Laboratory (84016)

**B.K. Afghan, Study Leader
R.J. Wilkinson, Collaborator**

Introduction

Analytical work with substances like chlorinated dioxins and furans calls for special laboratory conditions. Because these substances must often be measured at the ultra-trace level, ultra-clean laboratory conditions are required to minimize contamination of the samples. Special laboratory conditions are also dictated by occupational health and safety considerations, given the hazardous nature of these substances. Since the early 80's, a study has been developed as part of the activities carried out within the NWRI Research and Applications Branch to cover the operation and maintenance of a clean and hazardous chemicals laboratory. As a result, support is provided to organizations located at CCIW and requiring access to such laboratory facilities as part of their work.

Results

As in previous years, there has been a steady demand for the specialized services of the laboratory, with most of the work involving chlorinated dioxins and furans and linked to a variety of research studies or operational programs.

Screening Techniques for Toxic Substances

(84017)

J.P. Sherry, Study Leader

Introduction

Conventional methods for the analysis of trace organic contaminants in environmental samples are generally time consuming and expensive. Often, too many samples extracted and cleaned-up before GC or GC/MS analysis are eventually shown to be contaminant free. The inclusion of screening steps in analytical protocols would greatly reduce costs, by the early elimination of contaminant-free samples from further analysis. Samples that test positive using the screening assay would be confirmed and quantified using conventional methods. Immunoassays (IAs) are among the most promising screening tests available.

Based on the classical antigen-antibody reaction, IAs are relatively simple, powerful and adaptable techniques for the rapid detection of trace levels of organic compounds. Most IAs cost about a few dollars per assay, although some commercially available kits can cost about \$20 per sample.

Current research interests pursued under this study include the development of radioimmunoassay (RIA) techniques for trace organic contaminants, and the determination of their performance characteristics with a variety of environmental matrices. IA techniques for PCDDs and herbicides have been studied. Eventually it is hoped to have a battery of screening tests for the detection of a range of environmental contaminants. This research addresses the need of various sectors within Environment Canada's Inland Waters Directorate to access efficient and effective techniques for the analysis of trace contaminants in environmental samples.

Results

In view of the commercial availability of histamine substituted with radiolabelled iodine atoms, a labelled histamine dioxin derivative was synthesized and characterized. The availability of such a dioxin derivative with high specific activity should enhance the performance of the radioimmunoassay (RIA) for PCDDs.

The development of a prototype RIA for PCDDs using tritium-labelled 2,3,7,8-TCDD as a radioligand was completed. The performance of the assay was evaluated in terms of the effects caused by several parameter modifications and through comparison with other assay techniques for sensitivity and specificity. When the new assay technique was modified for use with monoclonal antibodies (MAB), preliminary results indicated the MAB-based assay to be more responsive and sensitive than a serum-based assay.

As part of this study, an extensive literature review on the immunoassay option in environmental chemistry has been compiled and is undergoing editing. One aspect addressed in the review is the feasibility of developing IAs for important herbicides such as glyphosate and diquat.

A study was designed and initiated for the application of a triazine immunoassay developed earlier under this research to a full scale field study carried out with the collaboration of staff of IWD-Ontario Region. Approximately 200 samples were collected and a sub-set of these samples has been prepared for future screening work.

Presentations

Sherry, J.P. and P.W. Albro. Radioimmunoassay of Chlorinated Dioxins: Use of [^3H] - labelled 2,3,7,8-TCDD as Radioligand. Presented at the Dioxin '90 Conference, Bayreuth, Germany, September 1990.

Development of Analytical Methods for Organic Compounds

(84018)

H.B. Lee, Study Leader

T.E. Peart, Collaborator

Introduction

The main focus of the research carried out under this study during last fiscal year has been the development of analytical methods whose need was identified as part of departmental initiatives to establish regulatory/control measures for pulp and paper mill effluents. The development of a reference method for the determination of levels of non-chlorinated dibenzo-*p*-dioxin (DBD) and dibenzofuran (DBF) in defoamers constituted one area of activity. This need arose after evidence became available linking the presence of DBD and DBF in substances used as defoamers during the chlorine bleaching process to increased levels of chlorinated dioxins and furans in pulpmill effluents. Work for the determination of toxic organic compounds in pulpmill effluents was continued with efforts concentrated on the development of a method applicable to resin and fatty acids in sediments.

Research assistance was also provided to the National Water Quality Laboratory to solve a recurring contamination and interference problem encountered during the determination of residual levels of phenoxy acidic herbicides in ambient water samples.

Results

A method for the determination of low levels of DBD and DBF in defoamers has been

documented through adaptations made to a procedure developed by scientists at the Pulp and Paper Research Institute of Canada. The method incorporates the analysis of defoamer extracts with a gas chromatography - mass spectrometry system operated in the selected ion monitoring mode, with a detection limit of 1 ng/g achievable for both DBD and DBF. The reference method was validated through an interlaboratory study designed and organized by staff of the NWRI Quality Assurance Project (*cf* Study 84027). Satisfactory precision and accuracy results were obtained by the laboratories participating in the QA study, thus indicating the reliability of the proposed reference method.

Resin and fatty acids (RFA) have been identified as the major contributors to the fish toxicity of pulp and paper mill effluents. These substances are found in the final effluents of many pulp and paper mills as well as in sediments downstream from the effluent discharge. Previous work in this area culminated in the development of a method for the determination of RFA levels in aqueous samples, including the derivatization of these compounds into their pentafluorobenzyl (PFB) esters. This approach has been found to be equally applicable to sediment samples, with an appropriate level of sensitivity readily achieved. The method has been successfully applied to the analysis of river sediments collected in the vicinity of pulpmill effluent discharges.

A great deal of effort has been devoted to the identification and elimination of the interference problem in the PFB ester procedure used by NWQL staff for the determination of acidic herbicides. Mass spectral analyses of sample extracts in the electron impact (EI) and negative ion chemical ionization (NICI) modes confirmed that the major interference peaks were saturated and unsaturated fatty acids. Many of the C_{12} - C_{18} fatty acids cause interference since they are present in the samples as natural contaminants at higher levels than the herbicides and have similar GC retention times and response factors once transformed into PFB esters. A cleanup step was devised to remove the fatty acids before the ECD analysis. Confirmation of the herbicide identities was achieved by either GC-MSD or NICI-MS.

Publications

Lee, H.B., C.E. Luthe, R.H. Voss and T.E. Peart. 1990. A Proposed Reference Method for the Determination of Dibenzofuran and Dibenzo-*p*-dioxin in Defoamers. NWRI Contribution 90-130.

Lee, H.B. and T.E. Peart. 1990. Determination of Resin and Fatty Acids in Sediments Near Pulpmill Locations. NWRI Contribution 90-150 (accepted for publication in the Journal of Chromatography).

Lee, H.B., T.E. Peart, J.M. Carron and H. Tse. 1990. Chemical Derivatization Analysis of Pesticide Residues. XI. An Improved Method for the Determination and Confirmation of Acidic Herbicides in Water. NWRI Contribution 90-151 (accepted for publication in the Journal of the AOAC).

Li, W.C., A.S.Y. Chau and H.B. Lee. 1991. Interlaboratory Study No. DF-1 for the Determination of Dibenzo-*p*-dioxin and Dibenzofuran in Defoamers. NWRI Contribution 91-01.

Presentations

Niimi, A.J. and H.B. Lee. Waterborne Resin Acid Uptake by Rainbow Trout. Presented at the 17th Annual Aquatic Toxicity Workshop, Vancouver, B.C., November 1990.

Development of Chromatography and Spectrometry Analytical Methods (84019)

V. Cheam, Study Leader

R.J. Desrosiers, J.F. Lechner and I. Sekerka, Collaborators

Introduction

In order to advance the understanding of atmospheric chemistry processes and to explain precipitation ionic balances, it remains important to have data on the levels of organic and inorganic acids in precipitation samples. As a continuation of a study initiated earlier, the work carried out last fiscal year was focussed on the development and assessment of various chromatography approaches for the analysis of acids in precipitation samples, with a view of identifying the one(s) most suitable for producing the data required under acid rain programs. Characteristics such as the number of different acids that can be analyzed, the analysis time, limits of detection, interference and overall usefulness are factors that were to be considered in this assessment.

The determination of very low levels of trace metals in environmental samples with existing methods often leads to unsatisfactory results, for instance the numerous "less than" values often reported by environmental analytical laboratories. Ultra-sensitive methods are needed for this type of analysis and spectroscopy methods using a laser light source are considered promising given the increased resolution and sensitivity that can be achieved over conventional techniques. A feasibility study was carried out under this study as a first step in the development of laser-excited atomic fluorescence spectrometry (LEAFS) facility at NWRI.

Results

Three ion chromatography methods (gradient, ion-exclusion and isocratic modes) and a few gas chromatography (GC) methods were investigated in order to determine which method covers the complete spectrum of acids commonly found in precipitation samples. The GC methods were not found to be suitable given the extensive sample pretreatment required and the fact that they are not cost effective when analyzing for formic and acetic acids. A comparative assessment of the three ion chromatography methods established that the best results are obtained when the method combines the gradient and ion-exclusion modes. In circumstances where only one mode could be used, the choice should go to the gradient mode as nearly all the acids of interest can be determined.

A laser-excited atomic fluorescence spectrometer (LEAFS) was successfully assembled using the Nd-YAG pumped dye laser facilities located at the University of Toronto, the first prototype of such an instrument ever built in Canada. The main characteristic of this instrument is the use of a tuned pulsed laser light beam as the excitation source responsible for the generation of trace metal atoms in the gas phase in the graphite furnace. Considering the sensitivity level achieved in the feasibility study, indications are that this technique should permit the determination of low- to sub-ppt levels of lead in samples. For the development of a LEAFS facility at NWRI, a copper vapour laser, a dye laser and a second harmonic generator have been incorporated in the assembly. Tests of this new system will be carried out during the coming months and its application for the determination of other trace elements investigated.

Publications

Cheam, V., I. Sekerka and R. Desrosiers. 1990. Laser-Excited Atomic Fluorescence Spectrophotometry - A Feasibility Study on Constructing a Spectrophotometer. NWRI Contribution 90-128.

Cheam, V. 1990. Ion-exclusion Chromatographic Determination of Organic Acids in Precipitation Samples. NWRI Contribution 90-145.

Presentations

Cheam, V. Lead Determination by Atomic Fluorescence. Presented at the "Lasers for the 90's" Symposium, Toronto, Ontario, May 1990.

QUALITY ASSURANCE

Organic Quality Assurance

(84021)

Yvonne D. Stokker, Study Leader

Introduction

Under this study various interlaboratory quality assurance studies focussed on the analysis of organic parameters are designed and carried out with the participation of various laboratories. These studies provide support to programs such as the National Dioxin QA Program and the Federal/Provincial QA Program or to the activities of organizations such as the Canadian Association of Pesticide Control Officials (CAPCO). Efforts are also devoted to the development, maintenance and characterization of stocks of analytical standards, particularly those containing organic contaminants. For instance, stock reference materials require periodical monitoring to ensure that their integrity is preserved under the conditions of their storage. As well, assistance is provided within the Quality Assurance Project for any QA matter involving organic parameters.

Results

The preparation of reference materials in ampules was supported this year by funding from the PESTMYOP program. A reference sediment extract, prepared from freeze-dried sediment material obtained from Lakes Erie and St. Clair, was fortified with 18 organochlorinated insecticides (OCs) including lindane, α -endosulfan, β -endosulfan, and *p,p'*-methoxychlor. 'Standard' solutions were also prepared to match the concentration levels in this sediment extract. The homogeneity of these ampules was established and the stability of the OCs was monitored

over an eight-month period. Ampules of standard solutions of chlorobenzenes were also prepared for inter- and intralaboratory QA/QC work.

Three organic quality assurance studies were conducted this year. In a study conducted under the auspices of the CAPCO National Check Sample Program, 35 laboratories across Canada submitted results for seven ampules of analytical standard solutions and sediment extracts containing the 18 OCs of interest. A review of the study data revealed that the majority of the participants were capable of accurately analyzing for the 18 OCs under study. One organic round-robin study was completed this year for the Federal/Provincial Interlaboratory Quality Assurance Program for the analysis of thirteen chlorinated hydrocarbons. The analysis results for the six injection-ready samples used in this study indicate that, of the four laboratories who provided results, only one demonstrated any significant problems with accuracy in analyses for low-level chlorobenzenes. National Dioxin Interlaboratory QC Study No. 3 was initiated in September 1990 and involved the analysis of dioxins and furans in four freeze-dried, naturally-contaminated reference sediments. While each one of the 14 participants showed considerable improvement with respect to interlaboratory comparability and intralaboratory precision over the results reported in similar previous studies, several participants, however, continued to produce biased data, particularly for the analysis of some of the furans.

The sediment Reference Materials (RMs) and Certified Reference Materials (CRMs) were again analyzed this year to verify the stability of their PAH, PCB, and chlorobenzene content. To date, there have been no signs of any losses or degradation of the natural levels of these contaminants in these reference materials. External sales of the sediment RMs and CRMs for the past fiscal year totalled about \$6K.

Publications

Stokker, Y.D. and E.A. Kokotich. 1991. Dredging Quality Control Study No. 5 (DQC-5). The Analysis of Polynuclear Aromatic Hydrocarbons, PCBs and Toxic Trace Metals in Sediment Reference Materials and Direct-Injection Solutions. NWRI Contribution 91-107.

Federal-Provincial and PPWB Quality Assurance Programs (84022)

H. Alkema, Study Leader

Introduction

The external quality assurance program instituted several years ago under this study provides support to the water quality analysis programs operated under various federal-provincial agreements, including the program of the Prairie Provinces Water Board (PPWB). Bimonthly interlaboratory comparison studies are carried out each year and involved the participation of federal and provincial government and private sector laboratories. Each study consists of samples to be analyzed for major ions, nutrients, trace metals and physical parameters.

At the completion of each study, the laboratory results submitted by the participants are compiled and evaluated via statistical methods. A study report is prepared in which laboratory performance is assessed through comparisons of results with target values or the magnitude of the standard deviation. Each participating laboratory is sent a copy of these study reports and encouraged to take corrective actions where indicated.

Results

Six interlaboratory studies were carried out as planned and an additional one, focusing on the analyzing of toxic organic compounds, was also conducted. These studies involved the participation of some 23 laboratories and as noted in previous years, the performance observed ranged from very poor to exceptionally good. An annual compilation of the reports resulting from these studies has been completed and published as an NWRI contribution.

Efforts are continuing in the development of a data base management system for the efficient storage and retrieval of historical data, including those generated under these quality assurance studies. The progress of this initiative remains gradual and dependent is on the level of resources available.

Publications

Alkema, H. 1990. Annual Report for the Interlaboratory Federal-Provincial Quality Assurance Program, Studies FP 45-56 (Sept. 89 - Aug. 90) for Inorganic Constituents in Waters. NWRI Contribution 90-148.

Alkema, H. 1990. Annual Report for the Interlaboratory PPWB QA Program, Studies PP 85-96 (Sept. 89 - Aug. 90) for Inorganic Constituents in Surface Waters. NWRI Contribution 90-149.

Presentations

Alkema, H. An Overview of the FPQA/PPWB Program and the Assessment Techniques. Presented to the PPWB Task Force on Water Quality Methods, Saskatoon, Saskatchewan, August 1990.

Alkema, H. On the Performance of the PPWB and FP Laboratories. Presented to staff of Environment Manitoba, Winnipeg, Manitoba, February 1991.

LRTAP Quality Assurance (84023)

K.I. Aspila, Study Leader
N. Arafat, Collaborator

Introduction

Under this on-going study, support is provided for the quality assurance aspects associated with the analytical data generated within the aquatic and atmospheric components of the Federal/Provincial Long Range Transport of Airborne Pollutants (LRTAP) program. The details of this study are established in close consultation with representatives of the Quality Assurance subgroup of the Research and Monitoring Coordinating Committee.

Since the beginning of this study in 1982, 26 interlaboratory comparison studies have been conducted, at a rate of three per year, and over 100 different laboratories have participated in one or more studies. Each study consists of ten natural water samples that are to be analyzed for some 20 constituents, ranging from major ions and nutrients to physical parameters. The results of each study are compiled in a data base management system and evaluated for bias using Youden's non-parametric technique. Laboratory specific performance reports are generated and sent to participants a few weeks after the completion of each study.

Results

Approximately 55 laboratories participated in each one of the three interlaboratory studies carried out last year. The performance of most participants continues to be quite good and the trend for steady improvement over the years has been maintained. In view of the significant

improvement observed in the precision of the data submitted, it was decided to tighten the criteria used as the basis for flagging deviant data.

As in previous years, under a cost recovery agreement between the U.S. Environmental Protection Agency and Environment Canada, 15 laboratories located in the U.S. and involved in the U.S. acid rain program were again invited to participate in the Canadian LRTAP interlaboratory studies.

Quality Assurance - Toxic Organic Substances in the Atmosphere (84024)

K.I. Aspila, Study Leader

Introduction

The atmospheric transport and deposition of toxic organic substances is continuing to receive an increase level of attention, particularly as it pertains to the Great Lakes Basin ecosystem. In this context, a new study is being developed to address the quality of the data and the comparability of the measurement systems associated with laboratory work carried out in Canada for the determination of toxic organic contaminants in samples of atmospheric origin.

Results

In this first year of the study most of the efforts have been concentrated on the logistic aspects of the collection and characterization of a large sample of rain. Last Fall, a 1000 litre sample of rain was collected from a clean portion of the roof surface of a large greenhouse located near Burlington, Ontario. After centrifugation and degassing, the sample was extracted for organic constituents to yield a 50 litre extract that is undergoing extensive analysis in the National Water Quality Laboratory. Barring unforeseen difficulties, this extract will be subdivided, spiked with specific contaminants and monitored for stability. Plans are being developed to use this material for conducting, in the coming months, an interlaboratory calibration study for laboratories specializing in the analysis of toxic substances in atmospheric samples. As well, the study will be designed to accommodate particular aspects of the atmospheric component of the Great Lakes Water Quality Agreement program.

Quality Assurance - Eulerian Model Evaluation Field Study
(84025)

K.I. Aspila, Study Leader

Introduction

Environment Canada, Environment Ontario, the US Environmental Protection Agency and the Electric Power Research Institute (US) operate atmospheric monitoring networks to monitor dry and wet fallout in various parts of North America. These agencies, for a period of 24 months, made a concerted effort to merge their network data and gather information jointly in order to evaluate various elements of the Eulerian model used for illustrating and predicting atmospheric transport processes.

At the request of the management group of the Eulerian Model Evaluation Field Study, interlaboratory comparison studies were initiated in 1989 to obtain data that could be used for assessing the comparability of the measurement data produced by laboratories participating in the program. Along with 4 laboratories formally involved in the Eulerian Model Study, 6 other laboratories were invited to participate in the QA program. In each monthly interlaboratory study, participating laboratories were requested to analyze 10 rain samples. The results were compiled in a data base management system and evaluated for bias, a significant statistical parameter in view of the intended merging of the results produced by the four network laboratories.

Results

The 27th and last study of this QA program was completed in July 1990. An overall assessment report has been prepared for submission to the Eulerian model study management team. As per the team's specific request, the report incorporates graphic representations of the bias observed in each laboratory data set, based on the applications of the median polish technique to each set of parameters measured.

CEPA Quality Assurance

(84027)

W.C. Li, Study Leader

A.S.Y. Chau, Collaborator

Introduction

Various programs linked to the implementation of assessment and regulatory/control provisions of the Canadian Environmental Protection Act (CEPA) depend crucially on the availability of reliable scientific measurement data. A few years ago, a study was specifically developed as part of the NWRI QA Project to provide quality assurance support to the data gathering activities in these areas. Activities carried out under this study include the design and conduct of interlaboratory QA studies focussed on CEPA Priority List Substances, the development of reference materials for particular substances entered on this list and the provision of expert advice on a wide range of associated QA/QC issues.

Results

Several reference standard solutions in ampuls were prepared for the following target substances: chlorophenols and non-chlorinated dibenzo-*p*-dioxin and dibenzofuran. Reference sediment extract materials were also prepared for chlorophenols.

As part of the preparation work for interlaboratory QA studies focusing on the determination of chlorophenols and organotin compounds, respectively, stability studies were carried out on appropriate reference materials developed for this purpose.

During last fiscal year, two interlaboratory QA studies were completed, one focusing on the analysis of levels of octachlorostyrene, hexachlorobenzene and hexachlorobutadiene in sediments and the other on butyltin in sediments. In addition, as part of a special project for the development of a reference method for the determination of dibenzo-*p*-dioxin and dibenzofuran in defoamers (*cf* Study 84018), a specially designed interlaboratory study for these substances was designed and carried out.

Publications

Chau, A.S.Y., W.C. Li, and H.B. Lee. 1990. Development of Sediment Extract Reference Samples for Selected Toxic Organic Contaminants - Part I. Total PCBs, Chlorobenzenes and Polynuclear Aromatic Hydrocarbons. NWRI Contribution 90-102.

Li, W.C., S.Z. Zhang, Y.K. Chau and A.S.Y. Chau. Preservation of Organics. Part IV. Stability of Bis(Tri-*n*-Butyltin) Oxide in Sediment Extracts. NWRI Contribution 90-139.

Zhang, S.Z., W.C. Li, Y.K. Chau and A.S.Y. Chau. Preservation of Organics, Part V. Stability of Butyltin Species in Sediment Extracts. NWRI Contribution 90-146.

Li, W.C., A.S.Y. Chau and H.B. Lee. Interlaboratory Study No. DF-1 for the Determination of Dibenzo-*p*-Dioxin and Dibenzofuran in Defoamers. NWRI Contribution 91-01.

Li, W.C. and A.S.Y. Chau. CEPA National Interlaboratory Comparison Study (CP-1): Analysis of Chlorophenols in Standard Solution and Sediment Extracts. NWRI Contribution 91-105.

Quality Assurance Activities for External Clients (84028)

K.I. Aspila, Study Leader

Introduction

The broad experience in quality assurance residing within the Quality Assurance Project is continuing to attract the attention of external clients interested in gaining access to this expertise. During the last fiscal year, a number of requests have resulted in client specific, cost recovery activities as detailed in the following paragraphs.

Results

Further to a request by staff of Environment Canada, Atmospheric Environment Service, standard pH reference water samples were prepared for distribution to six field laboratories as part of an audit of their performance.

Under a contractual arrangement with the British Columbia Ministry of Environment, blind audit samples were provided to assist in the performance monitoring of laboratories contracted by the provincial agency. Also, four specifically designed interlaboratory studies were carried out to evaluate and report on the performance of some 60 laboratories that could become involved in the analysis of industrial effluent discharges in relation to provincial regulations recently enacted.

Assistance was provided to staff of Environment Canada's Wastewater Technology Centre, Burlington, Ontario, in support of their involvement with the Ontario Ministry of the

Environment for assessing the capability and performance of laboratories carrying out work under the Municipal-Industrial Strategy for Abatement (MISA) program. This contract work involved the conduct of four interlaboratory studies focussed on pH, total phosphorus, soluble solids and biological oxygen demand as the parameters of interest.

Under funding provided by the Canadian Association of Environmental Analytical Laboratories, two interlaboratory studies for major ions and trace metal levels in water samples were carried out with the participation of over 50 Canadian laboratories. The data generated in these studies will assist the Association in assessing the performance of laboratories seeking accreditation from the Association.

HYDRAULIC STUDIES

The Surface Wave Dynamics Experiment (SWADE)

(84031)

M.A. Donelan, Study Leader

Introduction

The effect of waves on the atmosphere-ocean/lake couplings for transfer of mass, momentum and energy and the resultant importance of these processes to weather prediction and climate change are now generally recognized. This situation gives added impetus to the thrust to understand wave dynamics on the open ocean/lake, over and above the usual concerns for public safety and property protection. The Surface Wave Dynamics Experiment (SWADE) was conceived with the primary goals of understanding the dynamics of the evolution of the wave field in the open ocean/lake, and determining the effect of waves on the air-sea transfer of momentum, heat and mass.

M. Donelan serves as the Chief Scientist in this study and two U.S. agencies, the U.S. Office of Naval Research and the U.S. National Aeronautics and Space Administration, have provided the largest share of the funding for the investigation. SWADE truly has an international dimension judging from the numerous other research activities being carried out in 8 different countries by staff dispersed in some 40 universities and institutes.

Results

The experiment was planned by a team of scientists of various expertise and executed successfully off the Atlantic coast in Virginia, U.S. between 1st October 1990 and 31st March 1991. Different sets of parameters were recorded during the field work portion of the experiment

through an elaborate data capture network comprising buoys of various types as well as several airborne systems. The enormous data sets acquired are far more comprehensive and detailed than have been generated in any previous wave experiment. Analyses of these data are just being put in place by the 40 scientists directly involved in SWADE.

Publications

Weller, R.A., M.A. Donelan, M.G. Briscoe and N.E. Huang. 1991. Riding the Crest: A Tale of Two Wave Experiments. *Bulletin of the American Meteorological Society* 72 (2) 163-183.

Fluvial Engineering

(84032)

P. Engel, Study Leader

Introduction

The fluvial engineering study is directed at gaining a better understanding of fluid mechanics, sediment transport in rivers, the development of new and improved techniques for monitoring river processes and flow-structure interaction, particularly cases where structural failure could lead to serious environmental consequences. Emphasis is placed on providing valuable information in support of relevant programs of Environment Canada, particularly those of the Water Resources Branch (WRB). Results are also often applicable to issues of interest to other departments and other water resources managers.

Results

During this fiscal year the provision of support to the Water Survey of Canada (WSC) was continued, particularly in relation to their efforts to develop new acoustic flow measuring technology, a calibration strategy for suspended sediment samplers and the establishment of quality control criteria for measurement of river discharge under ice cover. Work was also conducted jointly with staff of the NWRI Rivers Research Branch (RRB) to establish the parameters which govern the performance of suspended sediment samplers. Research on transport of sediment in open channel flow was also continued.

The activities in the area of acoustic flow measurement technology development included an evaluation of a meter presently being developed by the U.S. Geological Survey (USGS) and

a comparison of the relative performance of three flow meter types. A methodology to measure mean velocity in stream flows with irregular velocity profile was developed. The efforts for the development of quality control criteria for discharge measurements in rivers with solid ice cover were focussed on the calibration of current meters. After establishing that the uncertainty of the calibrations is a function of the calibration process itself, detailed tests were conducted to address this issue. Work on the application of a three-dimensional numerical model to flow measurements in rivers with solid ice cover, conducted jointly RRB and RAB, is underway.

As part of the development of a comprehensive strategy for the calibration of suspended sediment samples, quality control tests on the sampler nozzles have been completed. A brief review of data on the WSC basket type bedload sampler was used to establish a link between the hydraulic efficiency and sampling efficiency.

Data obtained from hydraulic model tests have been applied to determine an efficient and economical stilling basin to prevent scour downstream of the Milk River Weir.

A preliminary analysis of extensive data from sediment transport tests conducted in the two metre flume located in the Hydraulics Laboratory has been completed. The test results provide a unique data set that should be useful in the study of the migration speeds of dunes, the friction factor associated with dunes, the validity of sediment transport equations and criteria on establishing steady state conditions during sediment transport studies in laboratory flumes can be obtained. Valuable collaboration in this work has been provided by RRB scientists.

Dimensional analysis, data from towing tank tests and from the literature were used to examine the behaviour of the US DH-81 suspended sediment sampler. Results have wide implications to sediment sampling in general and are pertinent to current WRB concerns. A more extensive series of tests to examine the factors governing the sampling rate of suspended sediment samplers for different flow velocities, different sizes of intake nozzles and air exhaust orifices was completed. This work will establish criteria for ensuring that sediment sampling is

conducted as close to iso-kinetic conditions as possible and provides as well the basic information for the eventual development of a self regulating, iso-kinetic sediment sampler.

P. Engel has been appointed as a member to the *USGS Advisory Committee for the Evaluation and Development of Current Meters*. The committee provides expert advice to USGS engineers engaged in examining river flow measurement instruments used presently and the development of better and more cost effective methods. This appointment provides an important link to strengthen the support provided to the Water Survey of Canada under this study.

Publications

Engel, P. 1990. On the Vertical Transit Method of Determining the Mean Velocity in Open Channel Flow. NWRI Contribution 90-130.

Engel, P. 1990. Considerations on the Hydraulic and Sampling Efficiency for Bed Load Samplers. NWRI Contribution 90-131.

Engel, P., E.J. Fast and J. Todd. 1990. Towing Tank Tests of the Accusonic Acoustic Flow Meter. NWRI Contribution 90-142.

Engel, P. and I.G. Droppo. 1990. Preliminary Tests for the Iso-Kinetic Calibration of DH-81 Suspended Sediment Sampler. NWRI Contribution 90-143.

Engel, P. 1991. Variability in the Velocity Coefficient of Suspended Sediment Sampler Nozzles. NWRI Contribution 91-109.

Engel, P., K. Wiebe and E. Fast. 1991. Relative Performance of Three Acoustic Flow Meters. NWRI Contribution 91-112.

Tsanis, I.K., M. Blaisdell, Y. Krestinitis, V.H. Chu and P. Engel. 1990. Physical and Mathematical Model Comparisons for Windermere Basin. Proceedings of the International Conference on Physical Modelling of Transport and Dispersion, August 7-10, 1990, Massachusetts Institute of Technology, Cambridge, Mass.

Coastal Engineering

(84033)

M.G. Skafel, Study Leader

C.T. Bishop, M.A. Donelan and J.C. Doering, Collaborators

Introduction

Physical processes in the coastal zone, the realm of coastal engineering, have a direct bearing on many environmental issues. Shoreline evolution, normally of public prominence only when the shorelines of our lakes and oceans are receding, is of direct relevance to the programmes of Environment Canada's Water Planning and Management Branch (WPMB). There are many uncertainties in our current understanding of shoreline evolution; we are currently focusing on the erosion of till (clay) shores, of particular interest to the WPM-Ontario Region's concerns in the Great Lakes. Suitable design criteria for coastal structures is vital to minimize environmental risks. Recent activities have concentrated on improving our understanding of wave forces on pipelines and wave descriptions for structural loading, both in support of the federal Panel on Energy Research and Development (PERD) program.

Results

With much of the lower Great Lakes shoreline composed of glacial till, it is important in the context of Great Lakes Shoreline Management programs to acquire a good understanding of the erosion by waves and the associated effects of varying lake levels on cohesive shorelines. Work in this area has been initiated under this study, with partial funding provided by the IWD WPM Branch and the collaboration of Drs. R. Nairn and J.W. Kamphuis (Queen's University). Full scale tests of the erosion of cohesive beach profiles by waves were started in the Hydraulics

Laboratory wind-wave flume facility and will continue well into fiscal year 91-92. Undisturbed till samples obtained from the top of Lake Erie bluffs at Port Alma, Ontario, will be used for these tests. Concurrently with the physical modelling experiments, numerical models are being developed and will be tested. The data generated in the experiments will be used particularly for validation purposes. The results of this study should also be of interest and relevance to the IJC Lake Level Reference Study.

The concept of sustainable development has innumerable applications. In the construction of offshore structures, care must be taken to minimize the chance of damage to the environment as well as design the most economical structures. Because wave processes cause the main loads to structures and are inherently random in nature, a succinct description of the joint distribution of wave heights and periods in shoaling water is vital to designs accommodating these two apparently conflicting requirements. In a study funded under the PERD program, field and laboratory experiments have been carried out to obtain data that will assist in the development of that description. The analysis of the experimental results has been focused for the time being on comparisons with existing theories, with plans to extend the theoretical approaches later on to strong shoaling conditions.

A hydraulic model study was designed and built to provide information that can be used during discussions between staff of NWRI Staff Services Division and Public Works Canada (PWC) regarding options available for the repair or rehabilitation of the breakwater structure at CCIW. A scale model of the breakwater was constructed in the Hydraulics Laboratory and the wave transmission and force characteristics of the structure were measured, with and without a floating tire breakwater (FTB) placed in front of the structure. The results of the study were incorporated in a report that was submitted to PWC staff last fall for their consideration.

Publications

Bishop, C.T. 1990. Historical Variation of Water Levels in Lakes Erie and Michigan-Huron. *J. Great Lakes Res.* 16 (3) 406-425.

Bishop, C.T. 1990. CCIW Breakwater Model Tests. NWRI Contribution 90-144.

Bishop, C.T. 1991. Rehabilitation of Vertical Thin-Walled Breakwater. NWRI Contribution 91-100.

Skafel, M.G. and C.T. Bishop. 1991. Comparison of Wave Climate Models. NWRI Contribution 91-101.

Donelan, M.A., F. Anctil and J.C. Doering. 1991. A Simple Method for Calculating the Velocity Field Beneath Irregular Waves. NWRI Contribution 91-111 (accepted for publication in *Coastal Engineering*).

Doering, J.C. and C.T. Bishop. 1990. Wave Height Prediction Using TMA. *Proc. Canadian Coastal Conference, National Research Council*, pp 241-255.

Bishop, C.T. 1990. Impact of Rubblemound Breakwater at Goderich. *Proc. Canadian Coastal Conference, National Research Council*, pp 405-419.

Skafel, M.G. and C.T. Bishop. 1990. Wave Forces on a Pipeline in a Trench. *Proc. Canadian Coastal Conference, National Research Council*, pp 453-464. Also in *Cdn. J. of Civil Eng.* 17 (4) 503-508.

Physics of the Air-Water Interface

(84034)

M. A. Donelan, Study Leader

Introduction

This study is focussed on fundamental processes related to the air-water interface, particularly topics such as surface waves, interfacial transport of mass, momentum and energy, wave related forces, and effect of breaking waves on surface mixing.

The important role played by air-water interfacial processes in the dynamics of oceans, lakes and atmospheres has long been recognized. Recent evidence of the effect of waves on the interfacial coupling has emphasized this role. Furthermore, the crucial issues of global warming and climatic change are strongly linked to the fate of anthropogenic gases, which itself depends to a great extent on the efficiency of their interfacial transfer. The mixing of surface pollutants by waves is an important aspect of understanding and predicting the impact of society on the environment. Finally, an improved understanding of the velocities beneath breaking waves reduces both the cost of engineering activities in the offshore as well as the risk to life and the environment.

Results

For the past twenty or thirty years, engineers have applied linear wave theory concepts to the calculation of forces on structures. While it is generally agreed that the approach works well at some distance beneath the interface, various *ad hoc* fixes have been devised to yield reasonable estimates of velocity near the surface - particularly under the crests - where the wave

related forces are strongest and the linear theory weakest. We have devised and tested a new method, based on linear theory but requiring no *ad hoc* assumptions, that yields accurate values at all depths. This work should make a significant positive impact in the field of offshore engineering.

Remote sensing of the oceans via satellites is a key aspect of the modern drive to improve weather forecasting and the prediction of climatic change. This is because *in situ* data on wind and waves is sparse and the cost of bringing ocean surface data up to the density and quality of land-based meteorological data is prohibitive. Satellite remote sensing promises to provide data on winds and waves on the ocean surface. A scatterometer is a specialized microwave radar instrument used for wind measurement. The second such device to be orbited is scheduled to be launched in 1991 aboard the European Research Satellite ERS-1, and another one, a NASA instrument, will be launched in 1995 by the Japanese space agency. Research aimed at improving the quality of the data from such scatterometers is clearly very relevant to the issues of weather prediction and climatic change. Working with scientists of the U.S. Naval Postgraduate School, we have completed tests on our research tower to clarify the sensitivity of those radars to relative wind direction. In addition, M. Donelan is a member of the NASA/NSCAT (Scatterometer) Science Working Team that has been assembled to provide advice to NASA on the design and use of the scatterometer.

Publications

- Donelan, M.A., N. Madsen, K. Kahma and I.K. Tsanis. 1990. Apparatus for Atmospheric Boundary Layer Measurements Over Waves. NWRI Contribution 90-127.
- Donelan, M.A., and W.H. Hui. 1990. Mechanics of Ocean Surface Waves. Chapter of a book "Surface Waves and Fluxes: Current Theory and Remote Sensing", G.L. Geernaert and W.J. Plant (Eds.). D. Reidel Publishing Company.

- Drennan, W.M., J. Fenton and M.A. Donelan. 1990. Numerical simulation of nonlinear wave groups, in 'Ocean wave mechanics, computational fluid dynamics and mathematical modelling' (Ed. Rahman, M.), Continuum Mechanics Publications, pp. 139-146.
- Donelan, M.A. *et al.* Research Needs for Better Wave Forecasting: Lewex Panel Discussion. Moderator: M. Donelan. John Hopkins APL Technical Digest, Volume 11, Nos. 3 & 4, 1990.
- Ancil, F., J.C. Doering and M.A. Donelan. A Theoretically Consistent Method for Computing the Velocity Field Beneath Wave Groups. Proc. of the NRC Workshop on Wave Groups, Ottawa, Ontario, December, 1990.
- Drennan, W.M. and M.A. Donelan. Evolving Velocity Fields Under Coalescing Groups. Proc. of the NRC Workshop on Wave Groups, Ottawa, Ontario, December, 1990.

Transfer of Toxic Gases

(84035)

M.A. Donelan, Study Leader

Introduction

Understanding and estimating gas transfer at air-water interfaces are critical aspects considered in studies on the fate of anthropogenic pollutants in the environment. Very little useful analysis of the transfer of synthetic organic substances of moderate molecular weight has been reported in the literature. This is partly because relevant studies of this process require a combination of physical and chemical methods and measurements as well as access to laboratory facilities appropriately designed and equipped for this kind of research. NWRI has supported under this study the design and construction of a modern gas transfer wind-wave facility. It is well equipped with appropriate instruments for physical and chemical measurements and two post-doctoral fellows contributing an expertise in physics and chemistry, respectively, are conducting an intense program of experiments to determine the transfer rate of various compounds.

Results

Coincident measurements of the transfer rate of chlorobenzene and water vapour have been made and the results have been analyzed in terms of aerodynamic roughness and wave properties.

Experiments have begun to explore the effect of (wave) fetch on the transfer rate of CO_2 and H_2O . The concentration measurements are being made with a Non-Dispersive Infra-Red

Absorption Analyser which switches between (sparged) water and air samples every 120 seconds. The water is "spiked" with CO_2 while the air is vented. The experiment begins with the closing of the system after which the concentrations are measured for several hours. Early indications are that transfer velocities for CO_2 and H_2O can be estimated within 5%. Such precise measurements will certainly facilitate the exploration of effects associated with fetch, temperature, etc.

A Fourier Transform Infra-Red (FTIR) Analyser has been purchased and tested. It will be used to replace the Non-Dispersive Analyser to permit measurements of transfer rates for a wide range of anthropogenic gases. Experiments on lindane and PCBs are scheduled to begin in early summer.

A new method for measuring the velocity profile very near a moving surface has been developed. The method makes use of non-intrusive (laser) measurements of elevation and slope to deduce the celerity of small waves and to infer the fluid velocity by comparison of these velocities with theoretical values.

Publications

Donelan, M.A., N. Merzi and M. Servos. 1990. Description of an Air-Tight Gas Transfer Flume and an Experimental Program for Mass Transfer at the Air-Water Interface. NWRI Contribution 90-147.

National Calibration Service

(84036)

W.B. Taylor, Study Leader

D. Fekyt, C. Bil, and B. Near, Collaborators

Introduction

The National Calibration Service was established further to NWRI's commitment to calibrate and repair all flow meters owned and used by the Water Survey of Canada (WSC), a component of Environment Canada's Water Resources Branch. The same type of services is also made available to outside clients on a cost recovery basis.

Results

Despite nearly 20 years of constant use, the tow tank facility used for the calibration work is in remarkably good condition, due mainly to the care and maintenance efforts of operating staff. While a major overhaul plan has been developed, financial constraints have hindered its smooth implementation and necessitated the replacement of components on an *ad hoc* basis.

During fiscal year 1990-91, 188 requests for services were actioned. A total of 795 calibrations and 446 current meter repairs were completed for WSC offices across Canada and for other clients such as universities, federal and provincial government agencies and private sector companies. External revenues totalling \$32.3K were generated during this period. This workload and level of revenue translate into a significant 40% increase over the situation experienced in the previous two years.

Hydraulics and Sedimentology Laboratory Operations

(84037)

W.B. Taylor, Study Leader
Technical Services Staff, Collaborators

Introduction

This study covers the support provided by specialized technical staff to hydraulics and geotechnical research and related activities carried out in the NWRI Hydraulics and Sedimentology Laboratories.

Results

In 1990-91, a total of 29 studies involving staff from the three NWRI Research Branches were supported within the 16 person-years complement of the Technical Services Group. Faced with support requests exceeding the available resources, the work assignments were organized to address the highest priorities. Adjustments were required in the scheduling of the maintenance work of various laboratory facilities, in light of the limited amount of resources available for this kind of work.

The level of activity in the Sedimentology Laboratory for sediment dating service was maintained throughout the year at a level that kept one contractor fully employed. In the Hydraulics and Sedimentology Laboratories, four student placements organized under co-operative programs provided valuable assistance for our activities.

Applied Research and Engineering

(84038)

Introduction

This study covers all third party revenue activities carried out under the Hydraulics Studies Project. In addition, administration and technical support is provided for similar activities carried out in the Hydraulics Laboratory through the involvement of Study Leaders from the Rivers Research Branch.

Results

Third party revenues generated in 1990-91 totalled \$72K, compared to an optimistic projection of \$120K made at the beginning of the fiscal year. Although 38 separate requests for services materialized, except for two of these exceeding \$10K each, all were in the range of only \$200 - \$1000 each.

Hydraulics Laboratory External Liaison

(84039)

C.T. Bishop, M.G. Skafel, W.B. Taylor and P. Engel, Collaborators

Introduction

The general objective for the activities carried out under this study is to increase awareness in Canada and in surrounding regions in the U.S.A. about the NWRI Hydraulics Laboratory. A better knowledge of the Laboratory's specialized facilities and of the conditions for gaining access to these should favour an increase in the level of activity in the laboratory as well as in the level of third party revenue generated.

Results

Issues no. 4 and 5 of the Hydraulics Laboratory Newsletter were distributed during the reporting period. The mailing list for the brochure was expanded, especially for the distribution covering the Province of Quebec and the Maritime Provinces, and now stands at approximately 700.

An advertisement was placed in the December 1990 issue of Environmental Science and Engineering, a Canadian trade journal with distribution of about 20,000 copies. The ad targeted flow measurement calibration studies in response to the Ontario Ministry of the Environment's recent MISA initiative. So far, the ad has elicited 12 responses requesting more information. Copies of the Hydraulics Laboratory brochure and of the latest Newsletter accompanied the reply letter prepared in response to these inquiries.

Based on a suspicion that many scientists at CCIW are not very well aware of the Hydraulic Laboratory's availability and capabilities, an information session was organized for the benefit of non-RAB Managers and Project Chiefs located at CCIW. Information on the Laboratory's facilities and on conditions governing their access to non-traditional users was presented. Considerable interest was generated, particularly in the perspective of how the Laboratory might be of benefit to various A-Base research activities.

C. Bishop visited Environment Canada staff located at the Centre St. Laurent, in Montreal, and the River Road Environmental Technology Centre, in Ottawa, to increase their awareness of the Hydraulics Laboratory and its availability in support of their research programs. Considerable interest was expressed by staff at Centre St. Laurent; this was followed by a visit to Burlington by two individuals. The prospects for future collaborative work look promising.

Following a presentation made by D. Doyle, a marketing consultant, as part of a workshop on Intellectual Property held at CCIW by C&P Technology Development Branch, C. Bishop met with Mr. Doyle to review the marketing program for the Hydraulics Laboratory. Under the current resources and mandate conditions, it was agreed that the approach followed currently is appropriate and worth pursuing at the present level of activity.

APPENDIX

List of Personnel and Areas of Expertise

Director's Office

Director

J. Lawrence, B.Sc., Ph.D. (Bristol)
Analytical Chemistry and Quality Assurance

Science Liaison Officer

R. Bisson, Ph.D. (Western Ontario)

Special Projects Coordinator

J.F. Ryan

Secretarial/Administrative

J. Burford
L. Heinrich
C. Kennedy
D. Weekes

Quality Assurance Project

Project Chief

A.S.Y. Chau, B.Sc. (British Columbia), M.Sc. (Carleton)
Reference Materials and Quality Assurance

Project Scientists

H. Alkema, B.T. (Ryerson)
Federal/Provincial QA Program and Preservation

K.I. Aspila, B.Sc., M.Sc. (Carleton)
Quality Assurance

W.C. Li, B.Sc. (National Taiwan), Ph.D. (Wisconsin)
Quality Assurance

Y. Stokker, B.Sc. (Guelph), M.Sc. (Queen's)
Organic Method Development and Quality Assurance

Technologist

N. Arafat, B.Sc. (Waterloo)

Analytical Chemistry Research Project

Project Chief

I. Sekerka, RNC., RNDR. (Prague), CSc. (Ostrava)
Electroanalytical Chemistry and Continuous Flow Analysis

Project Scientists

B.K. Afghan, B.Sc. (Sind), D.I.C. (I.C., London), Ph.D. (London)
Liquid Chromatography

D.J. Anthony, B.Sc. (McMaster)
Spectroscopy and Sample Pre-Concentration

V.F. Cheam, B.S., Ph.D. (Oklahoma)
Ion-Chromatography and Spectroscopy

S. Daniels, B.S., M.S. (Louisiana), Ph.D. (Waterloo)
Electrokinetic Methods

H.B. Lee, B.Sc. (Hong Kong), Ph.D. (McMaster)
Gas Chromatography, GC/MSD and High Pressure Liquid Chromatography

F.I. Onuska, P.Chem.Eng. (Bratislava), M.Sc. (Prague), CSc. (Brno), Ph.D. (Waterloo)
Gas Chromatography, GC/MS and Separation Techniques

B.F. Scott, B.Sc., M.A., Ph.D. (Toronto)
High Pressure Liquid Chromatography and Gas Chromatography

J.P. Sherry, B.Sc., Ph.D. (N.U.I.)
Mycology and Radioimmunoassay

Research Technologists

J.F. Lechner
K.A. Terry
R.J. Wilkinson

Hydraulics Studies Project

Project Chief

M.G. Skafel, B.A., B.E., M.Sc. (Saskatchewan), Ph.D. (Cambridge), P.Eng.
Coastal Engineering

Project Scientists

C.T. Bishop, B.Sc., M.Sc. (Queen's), P.Eng.
Coastal Engineering

M.A. Donelan, B.Eng. (McGill), Ph.D. (B.C.)
Air-Water Interaction

P. Engel, B.A.Sc., M.A.Sc. (Waterloo), P.Eng.
Fluvial Engineering

Technologists

W.B. Taylor, Head, Technical Services Section

D. Beesley
C. Bil
J. Dalton
D. Doede
G. Duncan
F. Dunnett
D. Fekyt
J. Heidt
W. Moody
B. Near
T. Nudds
R. Stephens
B. Trapp
G. Voros